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Expt. No. 1 .....

AIM:- To determine the Planck's constant using LEDs of at least 4 different colours.

THEORY:- Planck's constant (h), a physical constant was introduced by German physicist named Max Planck in 1900. The significance of Planck's constant is that 'quanta' (small packets of energy) can be determined by frequency of radiation and Planck's constant. It describes the behaviour of particle and waves at atomic level as well as the particle nature of light.

An LED is a two terminal semiconductor light source. In the unbaised condition a potential barrier is developed across the p-n junction of the LED. When we connect the LED to an external voltage in the forward biased direction the height of potential barrier ~~becomes~~ across the p-n junction is reduced. At a particular voltage the height of potential barrier becomes very low and the LED starts glowing, i.e, in the forward biased condition electrons crossing the junction are excited, and when they return to their normal state, energy is emitted. This particular voltage is called the Knee voltage or the threshold voltage. Once the Knee voltage is reached, the current may increase but the voltage doesnot change

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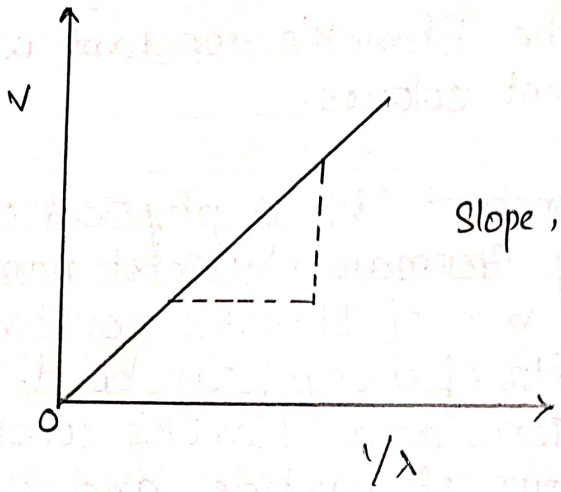

Slope, $S = \frac{he}{e}$

fig :- V vs. 1/λ graph

The light energy emitted during forward biasing is given as;

$$E = \frac{hc}{\lambda} \longrightarrow (1)$$

where c – velocity of light
h – Planck's constant
λ – wavelength of light.

If V is the forward voltage applied across the LED when it begins to emit light (the 'Knee voltage), the energy given to electrons crossing the junction is.

$$E = eV \longrightarrow (2)$$

From equⁿ (1) and (2)

$$eV = \frac{hc}{\lambda} \longrightarrow (3)$$

The Knee voltage V can be measured from LED's with different values of λ

$$V = \frac{hc}{e}\left(\frac{1}{\lambda}\right). \longrightarrow (4)$$

Now from equⁿ (4), we see that the slopes of a graph of V on the vertical axis vs. $1/\lambda$ on the horizontal axis is

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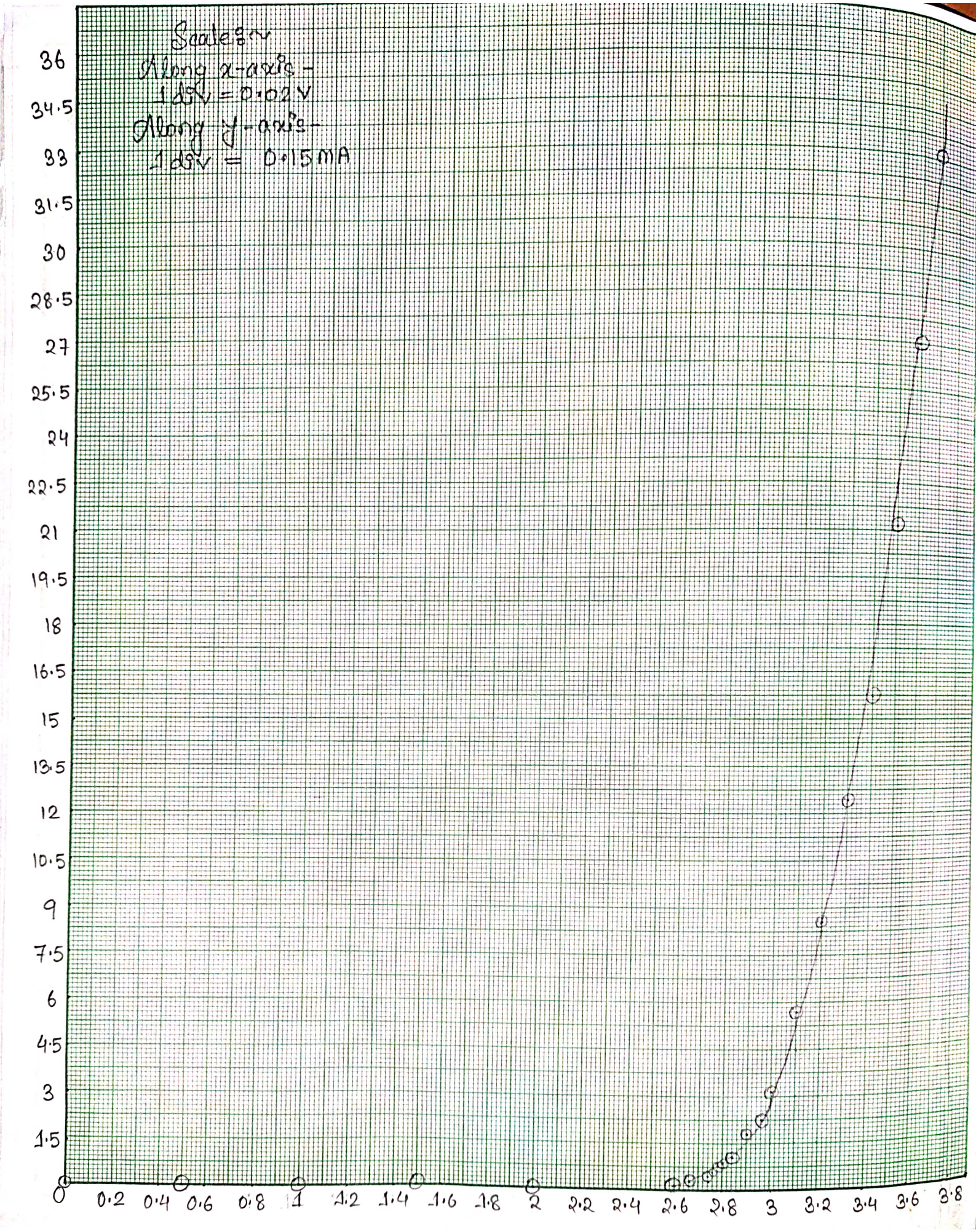

Scale:-
Along x-axis -
1 div = 0.02 V
Along y-axis -
1 div = 0.15 mA
36
34.5
33
31.5
30
28.5
27
25.5
24
22.5
21
19.5
18
16.5
15
13.5
12
10.5
9
7.5
6
4.5
3
1.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8

$$S = \frac{hc}{e}$$

To determine the value of Planck's constant h,

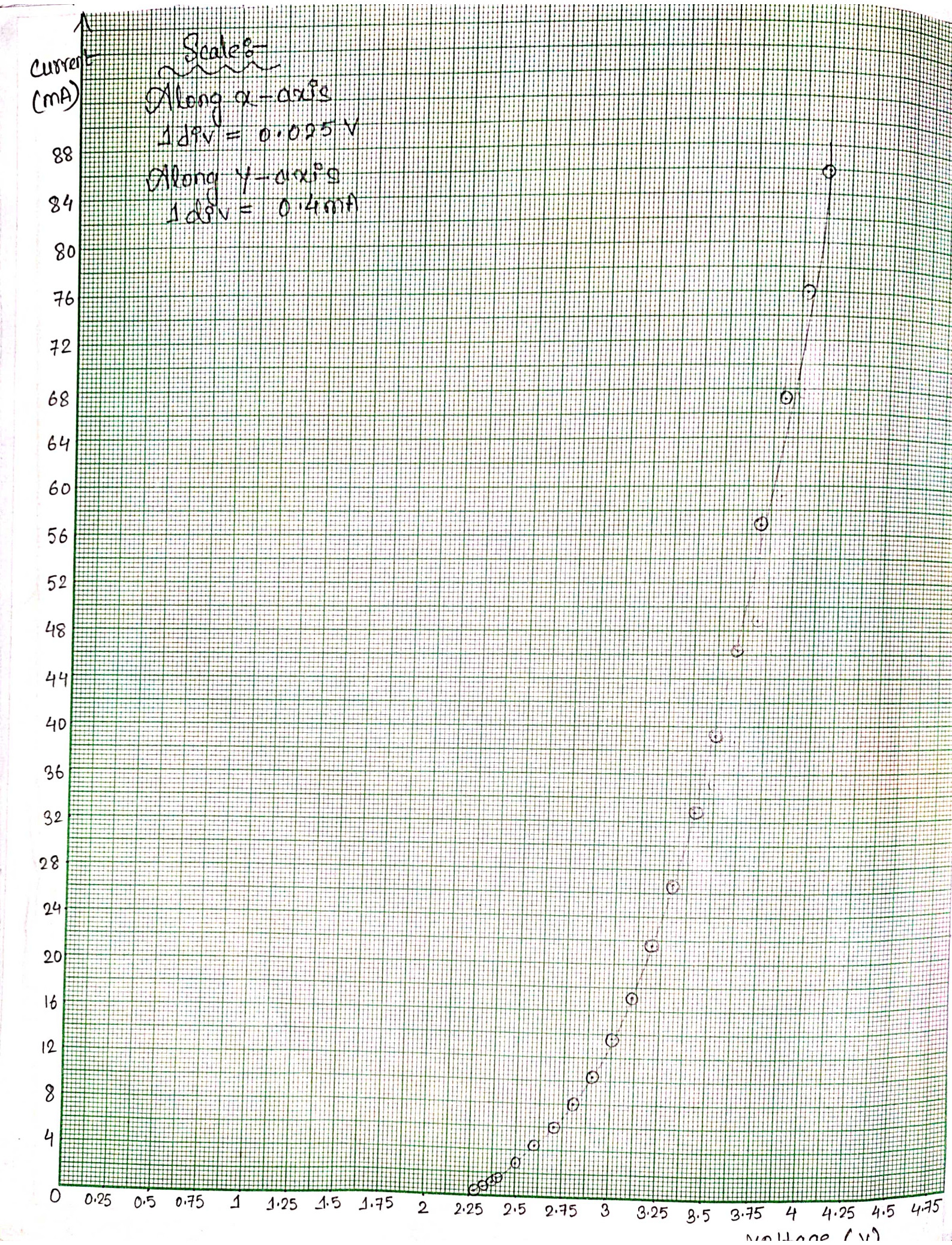
$$h = \frac{e}{c} S$$

Alternatively, $\boxed{h = \frac{e \lambda v}{c}}$

EXPERIMENTAL TABLES :-

BLUE :-

Voltage (v)	I (in mA)	Voltage (v)	I (in mA)
0	0	2.82	1
0.5	0	2.83	1.1
1	0	2.85	1.2
1.5	0	2.9	1.8
2	0	2.95	2.3
2.59	0.1	3	3.1
2.6	0.2	3.1	5.7
2.65	0.3	3.2	8.5
2.7	0.4	3.3	12.4
2.73	0.5	3.4	17.3
2.75	0.6	3.5	22.6
2.77	0.7	3.6	28.5
2.79	0.8	3.7	34.7
2.8	0.9		


Current (mA)
Scale:-
Along x-axis
1 div = 0.025 V
Along Y-axis
1 div = 0.4 mA
88
84
80
76
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
4.25
4.5
4.75

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GREEN:-

Voltage (in v)	I (in mA)	Voltage (in v)	I (in mA)
0	0	2.9	10.3
0.5	0	3	13.4
1.5	0	3.1	17
2.18	0.1	3.2	21.5
2.21	0.2	3.3	26.7
2.23	0.3	3.4	32.8
2.26	0.4	3.5	39.2
2.27	0.5	3.6	46.5
2.29	0.6	3.7	56.6
2.31	0.7	3.8	67.3
2.32	0.8	3.9	76
2.33	0.9	4	85.9
2.34	1	~~4.1~~	
2.35	1.1		
2.36	1.2		
2.37	1.3		
2.38	1.4		
2.39	1.5		
2.4	1.6		
2.41	1.7		
2.5	2.8		
2.6	4.2		
2.7	6		
2.8	7.9		

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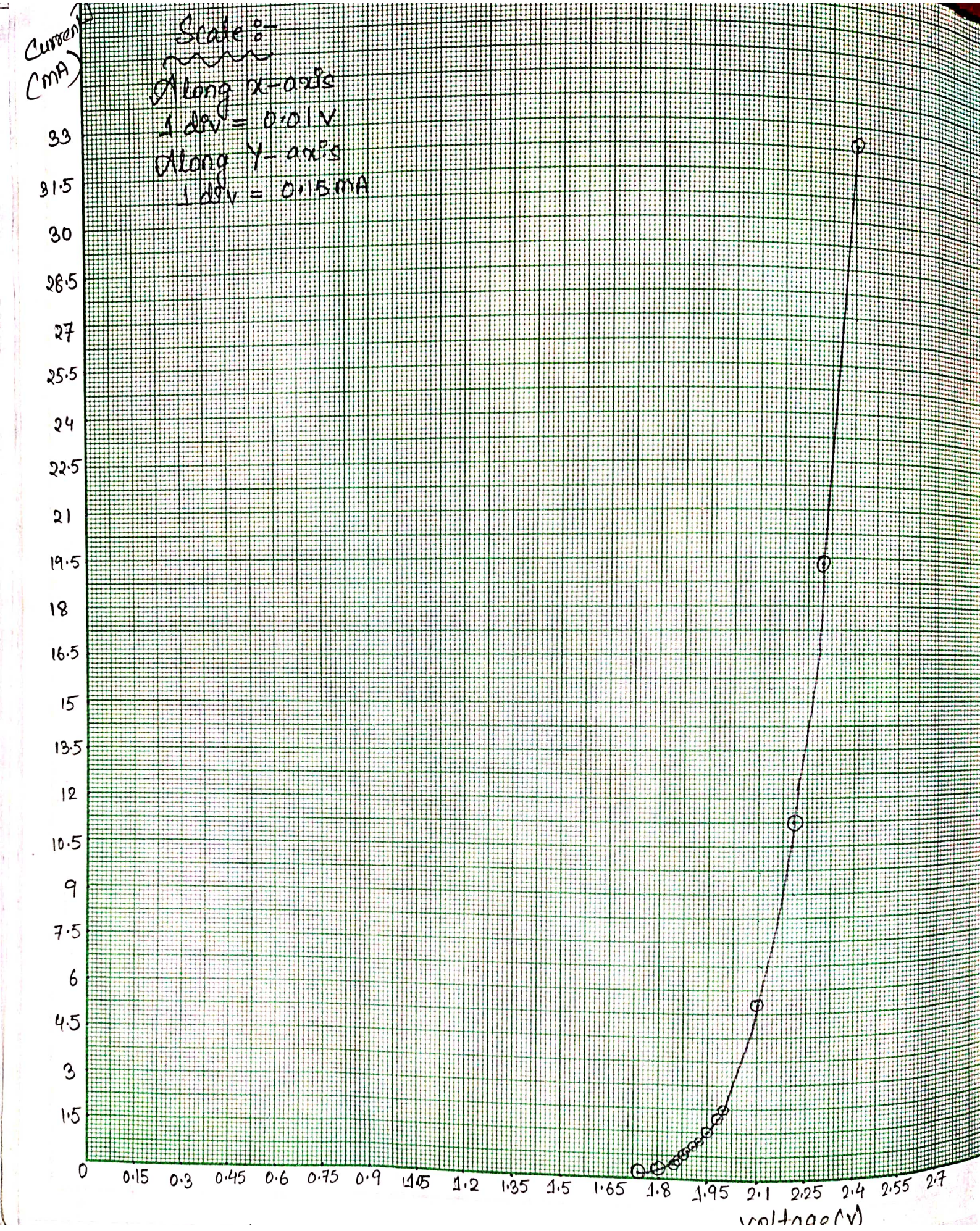
Current (mA)
Scale :-
Along x-axis
1 div = 0.01 V
Along y-axis
1 div = 0.15 mA
33
31.5
30
28.5
27
25.5
24
22.5
21
19.5
18
16.5
15
13.5
12
10.5
9
7.5
6
4.5
3
1.5
0
0.15
0.3
0.45
0.6
0.75
0.9
1.05
1.2
1.35
1.5
1.65
1.8
1.95
2.1
2.25
2.4
2.55
2.7
Voltage (V)

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Yellow:-

Voltage (in V)	I (in mA)	Voltage (in V)	I (in mA)
0	0	2.2	11.3
0.5	0	2.3	19.4
1	0	2.4	32.6
1.74	0.1		
1.78	0.2		
1.8	0.3		
1.82	0.4		
1.84	0.5		
1.86	0.6		
1.87	0.7		
1.88	0.8		
1.89	0.9		
1.9	1		
1.91	1.1		
1.92	1.2		
1.93	1.3		
1.94	1.4		
1.95	1.5		
1.96	1.7		
1.97	1.8		
1.98	2		
1.99	2.2		
2	2.4		
2.1	5.7		

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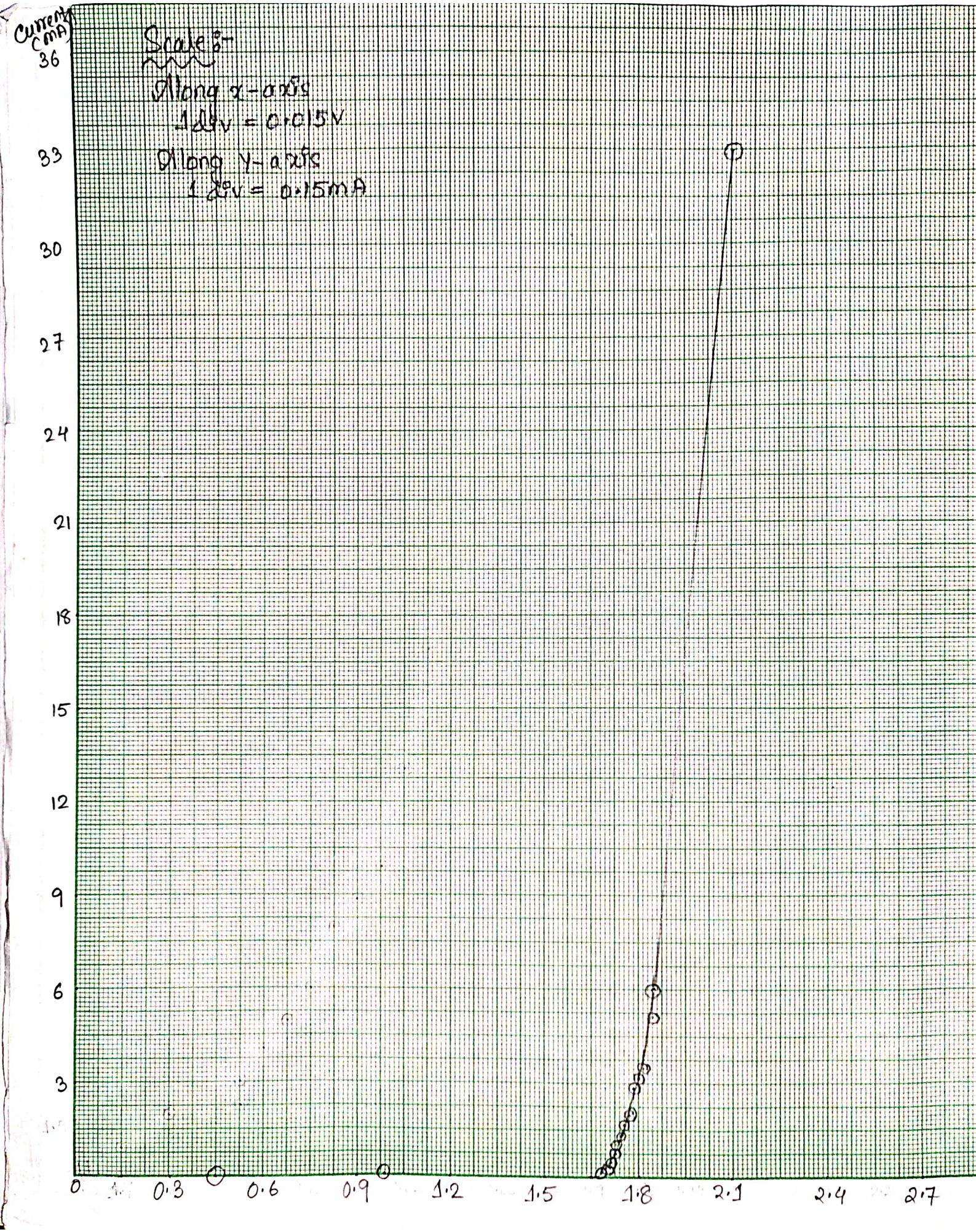
Current (mA)
Scale:-
Along x-axis
1 div = 0.015V
Along Y-axis
1 div = 0.15mA
36
33
30
27
24
21
18
15
12
9
6
3
0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7

Red :-

Voltage (in V)	I (in mA)
0	0
0.5	0
1	0
1.7	0.1
1.72	0.2
1.75	0.3
1.76	0.4
1.77	0.5
1.78	0.6
1.79	0.8
1.8	0.9
1.81	1
1.82	1.3
1.83	1.7
1.84	1.8
1.85	2
1.86	2.4
1.87	2.8
1.88	3.1
1.89	3.5
1.92	5.1
1.93	5.9
2.1	33.1

Infrared :-

Voltage (in V)	I (in mA)
0	0
0.5	0
0.96	0.1
0.98	0.2
1	0.3
1.01	0.4
1.02	0.5
1.03	0.6
1.05	1.1
1.06	1.4
1.07	1.5
1.1	3.4
1.11	4.1
1.13	6.6
1.15	8.8
1.16	10.9
1.18	16.1
1.2	19.5
1.22	28.5
1.24	33
1.26	38.6
1.28	46.6

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Current (mA)
36
33
30
27
24
21
18
15
12
9
6
3

① Blue LED :-

Wavelength, $\lambda_1 = 470\,nm$, Knee voltage $V_1 = 2.7\,V$ ~~2.95~~

$\therefore h_1 = \frac{e}{c} \times \lambda V$

$= \frac{1.6 \times 10^{-19}}{3 \times 10^8} \cdot 470 \times 10^{-9} \times 2.7$ ~~2.95~~

$= 6.7 \times 10^{-34}\,J$

② Green LED :-

Wavelength $\lambda_2 = 530\,nm$, Knee voltage $V_2 = 2.4\,V$

$\therefore h_2 = \frac{e}{c} \lambda V = 6.78 \times 10^{-34}\,J$

③ Yellow LED :-

Wavelength $\lambda_3 = 580\,nm$, Knee voltage $V_3 = 2.2\,V$

$\therefore h_3 = 6.80 \times 10^{-34}\,J$

④ Red LED :-

Wavelength $\lambda_4 = 700\,nm$, Knee voltage $V_4 = 1.85\,V$.

$\therefore h_4 = 6.72 \times 10^{-34}\,J$

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Calculation of Planck's constant h :-

For Blue LED, $h_1 = 6.7 \times 10^{-34}$ J

For Green LED, $h_2 = 6.78 \times 10^{-34}$ J

For Yellow LED, $h_3 = 6.80 \times 10^{-34}$ J.

For Red LED, $h_4 = 6.72 \times 10^{-34}$ J.

$\therefore$ Mean $h = \dfrac{h_1 + h_2 + h_3 + h_4}{4}$

$= 6.75 \times 10^{-34}$ J.

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1/λ Vs. V

Scale :-

Along x-axis

1 cm = $0.015 \times 10^{6}\ m^{-1}$

Along y-axis

1 cm = 0.015 V.

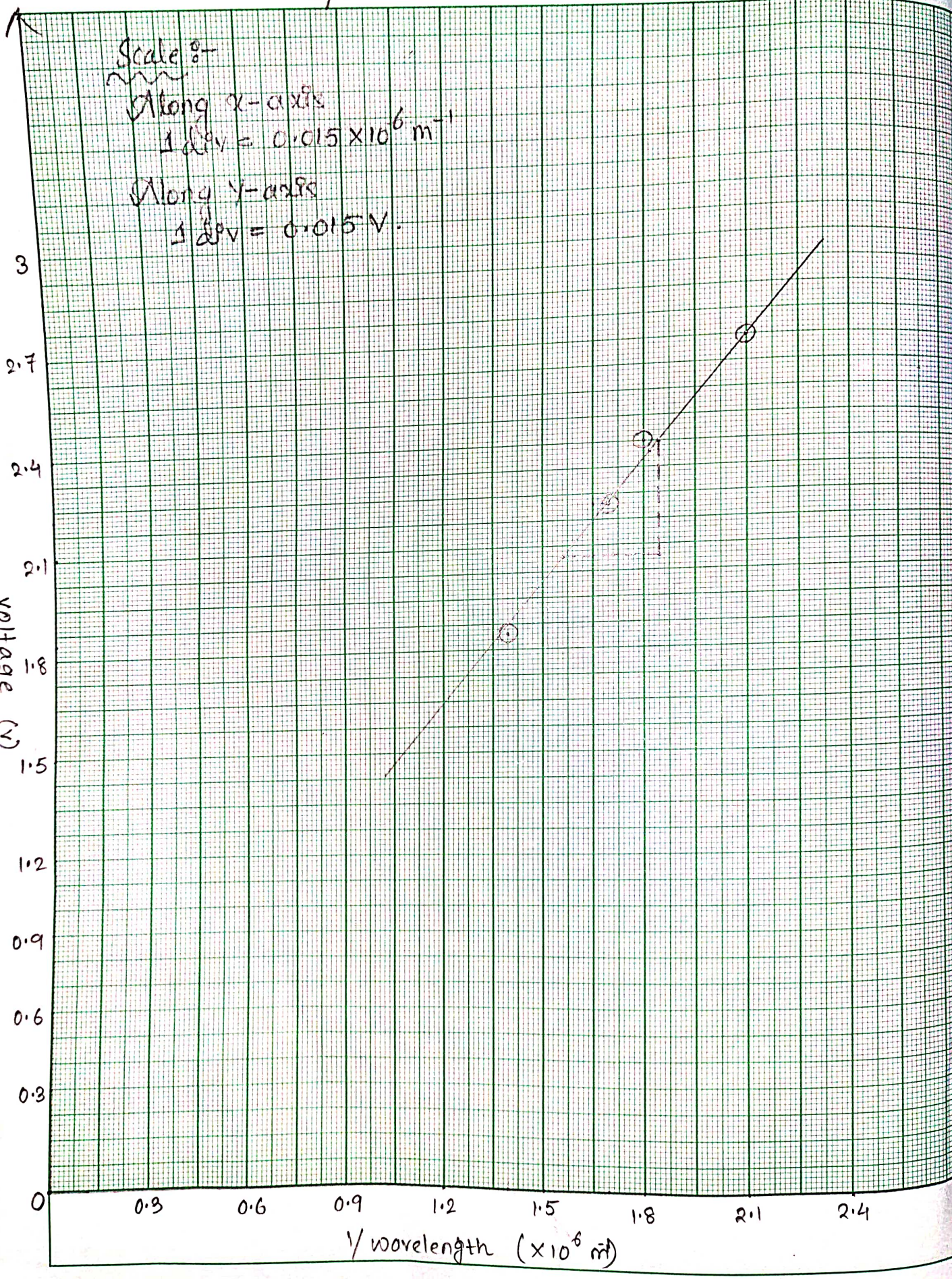

Table :- Graph between 1/wavelength and voltage.

Colour of LED	1/wavelength ($\times 10^6$ m^{-1})	Voltage (V)
Blue	2.1	2.7
Green	1.8	2.4
Yellow	1.7	2.2
Red	1.4	1.85

Calculation of Planck's constant (h) from the graph :-

Slope of the graph = 1.15789×10^{-6} Vm

Now, Slope of the graph, $S = \frac{hc}{e}$

$\therefore h = \frac{Se}{c} = \frac{1.15789 \times 10^{-6} \times 1.6 \times 10^{-19}}{3 \times 10^8}$

$= 6.17 \times 10^{-34}$ J.

RESULT :- Hence, Planck's constant obtained experimentally and graphically are approximately same to the actual value of Planck's constant.

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TECHNICAL SPECIFICATIONS:

MAINS SUPPLY : 230V ± 10%

FUSE : 0.5A
DC POWER SUPPLY : 0-5V

LED
Type : semiconductor
Size : 5mm
Colour : Blue, Green, Yellow, Red, Infra-red

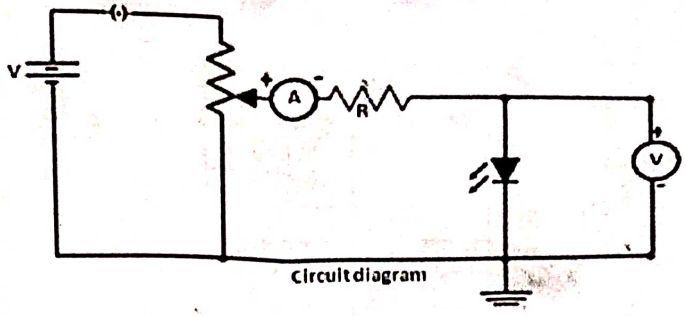
WAVELENGTH
Blue : 460nm
Green : 510nm
Yellow : 590nm
Red : 650nm

DC VOLTMETER
Type : LED
Display : $3^{1/2}$ digits
Range : 200mV / 20V

DC AMMETER
Type : LED
Display : $3^{1/2}$ digits
Range : 2mA / 200mA

INCLUDED ACCESSORIES

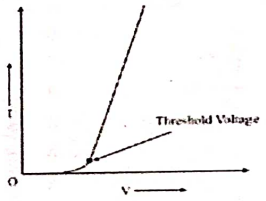
4mm Patch Cords : 8 nos.
Mains Cord : 1 nos.



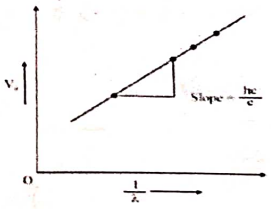
Circuit diagram

PROCEDURE

1. Connect the circuit as per circuit diagram.
2. Connect any one LED as per your choice.
3. Set the range of DC voltmeter to 20V.
4. Keeping the voltage knob in the minimum position, switch on the power supply.
5. Vary the DC voltage slowly by increasing the voltage knob and observe the LED.
6. Note the voltage when the LED just starts to glow.
7. Repeat the same procedures for LEDs of different colours.
8. **Using the formula** $h=\frac{e}{c}\lambda V$, **calculate the value of Planck's Constant for different LEDs.**
9. Keep increasing the DC voltage at fixed intervals (say 0.1V) and note the current flowing through the circuit in the DC ammeter.
10. Make sure the current does not exceed the current limiting value of LED.
11. Plot the current along Y-axis and the corresponding voltage along X-axis.
12. Note the 'knee voltage' or 'threshold voltage (V_0)' for each LED as shown in figure.



13. **Using the formula** $h=\frac{e}{c}\lambda V_0$, **calculate the value of Planck's Constant for different LEDs.**
14. Next, plot a graph between the threshold voltage and wavelength for different colours of LED. You will get a slope 'S' as shown in figure, where S=hc/e.



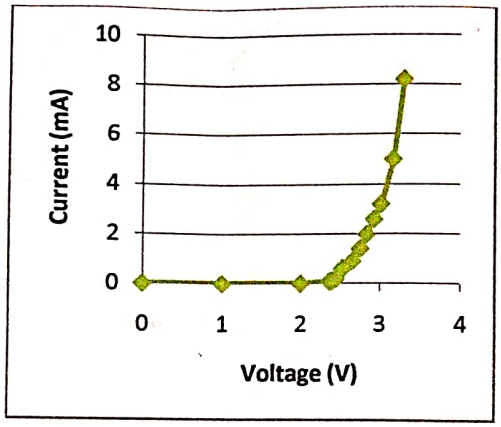
15. **Using the formula** $h=\frac{Se}{c}$, **calculate the value of Planck's Constant.**

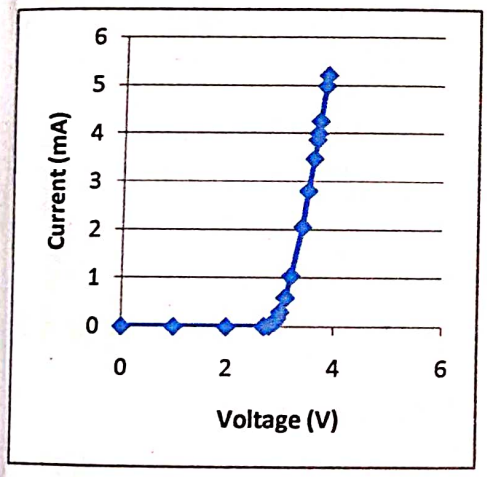
OBSERVATION TABLE

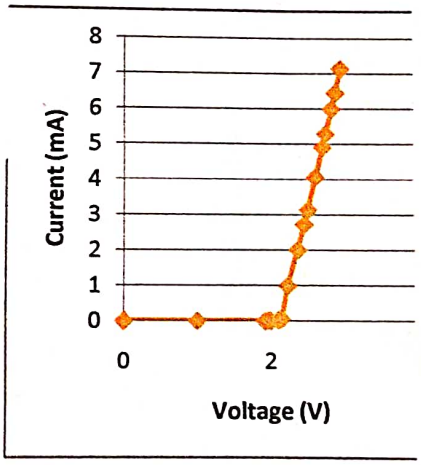
BLUE	
V (In Volt)	I (In mA)
0	0
1	0
2	0
2.7	0.01
2.8	0.02
2.9	0.1
2.95	0.17
3	0.3
3.1	0.6
3.2	1.05
3.4	2.06
3.5	2.8
3.6	3.47
3.65	3.87
3.67	4
3.7	4.25
3.8	4.98
3.83	5.2

GREEN	
V(In Volt)	I (In mA)
0	0
1	0
2	0.01
2.37	0.08
2.4	0.1
2.45	0.2
2.53	0.6
2.65	0.9
2.75	1.4
2.83	2
2.92	2.6
3.01	3.2
3.16	5
3.29	8.2

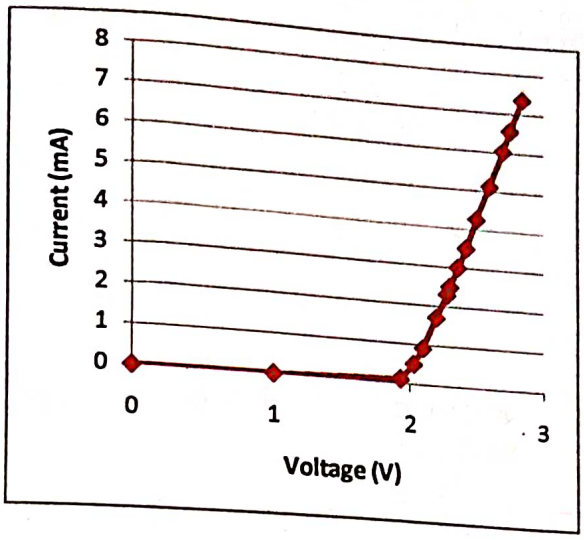
YELLOW	
V (In Volt)	I (In mA)
0	0
1	0
2	0
1.92	0
1.97	0.01
2.1	0.02
2.14	0.05
2.22	1
2.36	2
2.45	2.73
2.5	3.14
2.6	4.06
2.7	4.92
2.74	5.3
2.82	6
2.87	6.45
2.94	7.15







RED	
V (in Volts)	I (in mA)
0	0
1	0
1.93	0.1
2.03	0.5
2.1	0.91
2.2	1.7
2.28	2.3
2.3	2.5
2.36	3
2.42	3.5
2.5	4.26
2.6	5.12
2.7	6.03
2.75	6.55
2.84	7.36



	1/wavelength (nm^{-1})	V (in V)
RED	1.5	1.93
YELLOW	1.6	2.14
GREEN	1.9	2.5
BLUE	2.1	2.9